Generation X

Flight Dynamics

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Flight Dynamics Overview

- Driving Requirements and Assumptions
- Overview of Orbit Options
- Overview of Transit Options
- Orbit Maintenance
- Issues and Concerns
- Summary

Flight Dynamics
Driving Requirements & Assumptions

- Mission Orbit is an L2 Co-linear Libration Orbit,
- No specified orbit amplitude parameters, e.g. large or small
- Possible use of Lunar Gravity Assist to minimize ΔV budget for small amplitude orbit

Flight Dynamics
L2 Orbit Options

- Large Lissajous:
  Direct Transfer
  (y-amplitude ~800K km)
  C3 = -0.677
  L2 Insertion ΔV= 0.68 m/s,
  First correction ΔV = 6.1 m/s

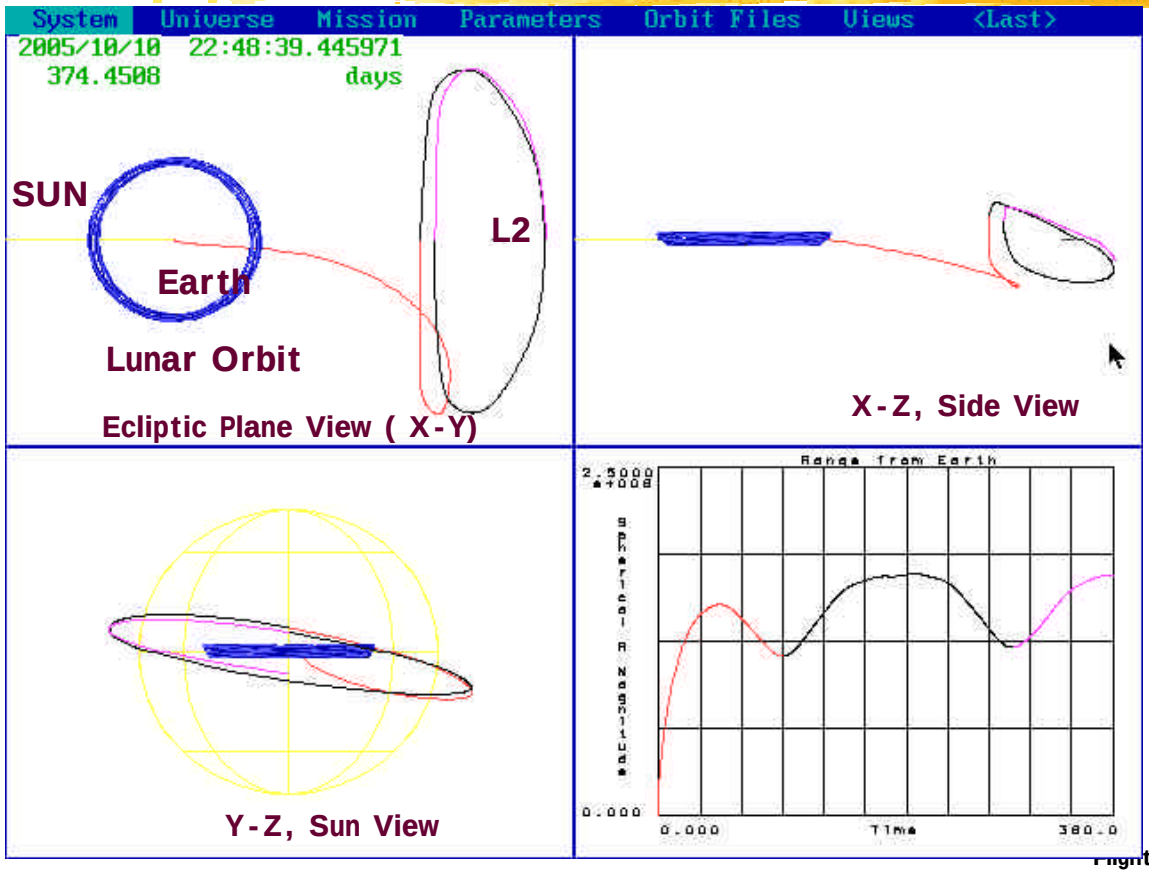
- Small Lissajous:
  Direct Transfer
  (y-amplitude ~ 400K km)
  C3 = -0.677
  L2 Insertion ΔV = 108 m/s
  First correction ΔV = 23 m/s

- Small Lissajous:
  Lunar Gravity Assist
  (y-amplitude ~ 200K km)
  C3 = -2.17
  Phasing loop ΔV_1 = 5.5 m/s
  L2 insertion ΔV_2 = 12.5 m/s

Flight Dynamics
Transfer to L2 Options

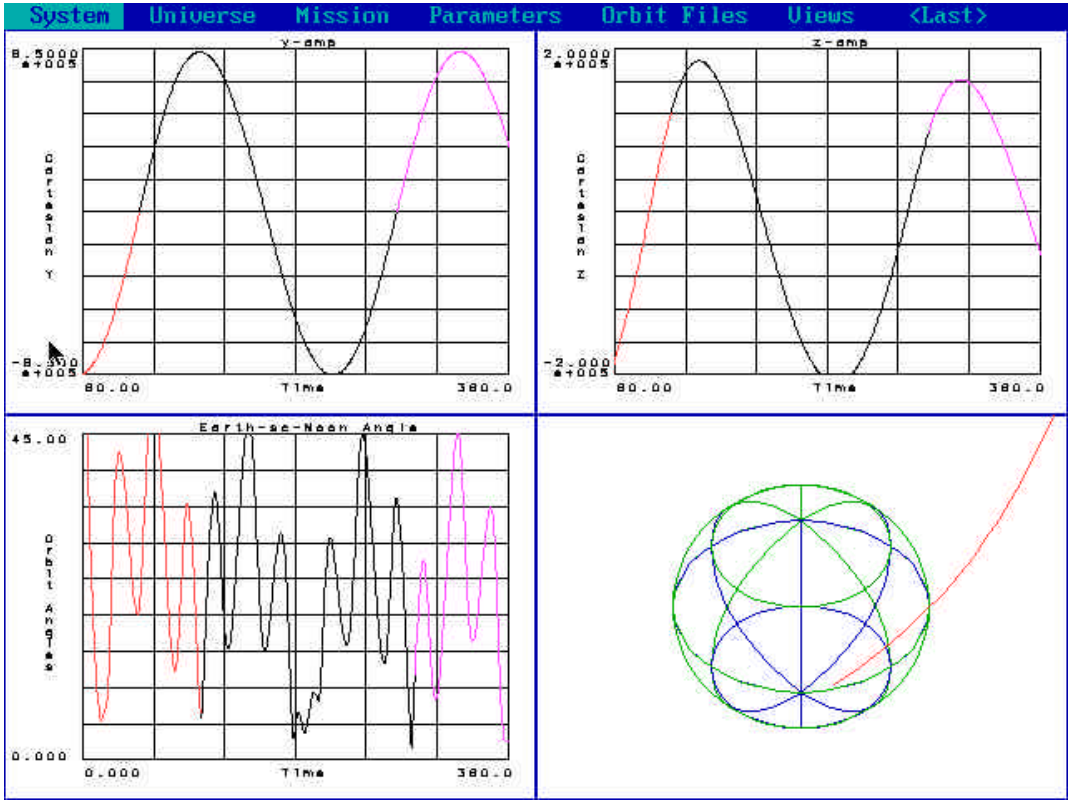
- **Direct Transfer**
  - High Thrust, impulsive maneuver
- **Low Thrust Transfer**
  - Low Thrust, continuous velocity direction
  - Still requires Lissajous Orbit Insertion (LOI)

Flight Dynamics
Option 1:Large Lissajous/Direct Transfer

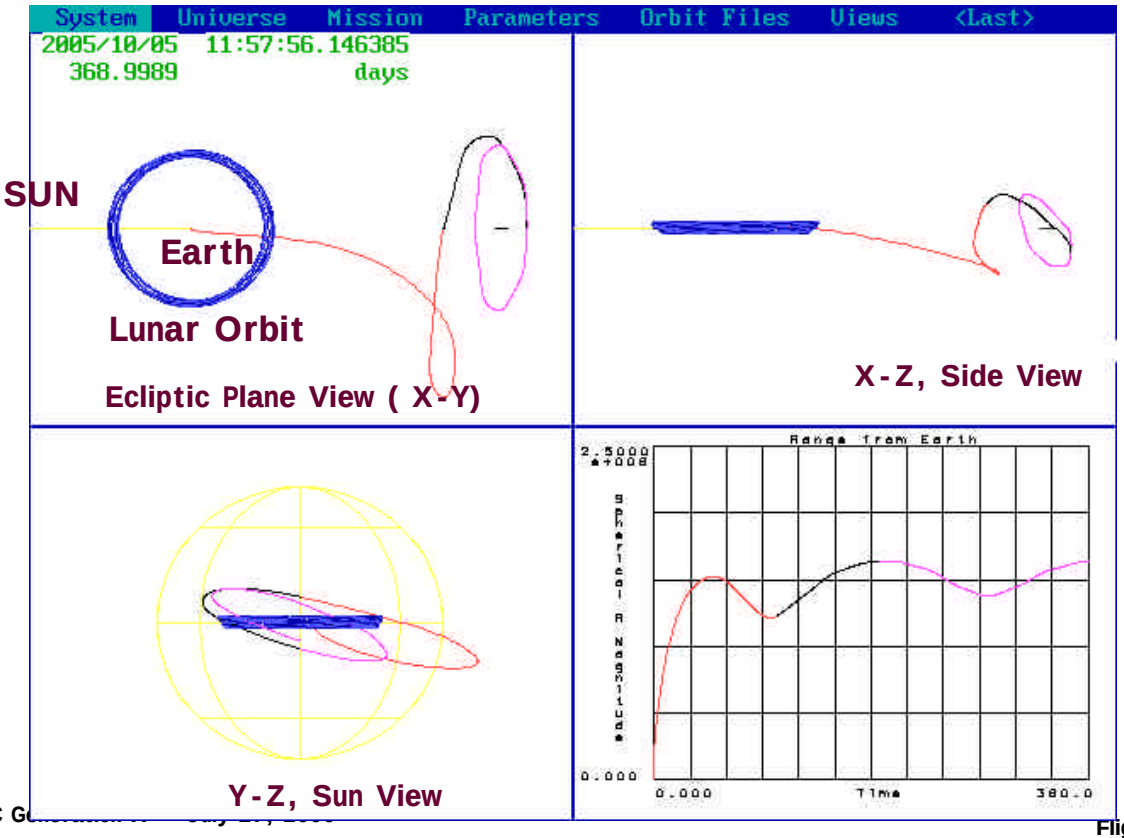


Flight Dynamics
Option 1:Large Lissajous/Direct Transfer

- Y-Amp ~ 800k
- Z-Amp ~ 200k
- Sun-S/C-Moon angles of 0-45 degrees

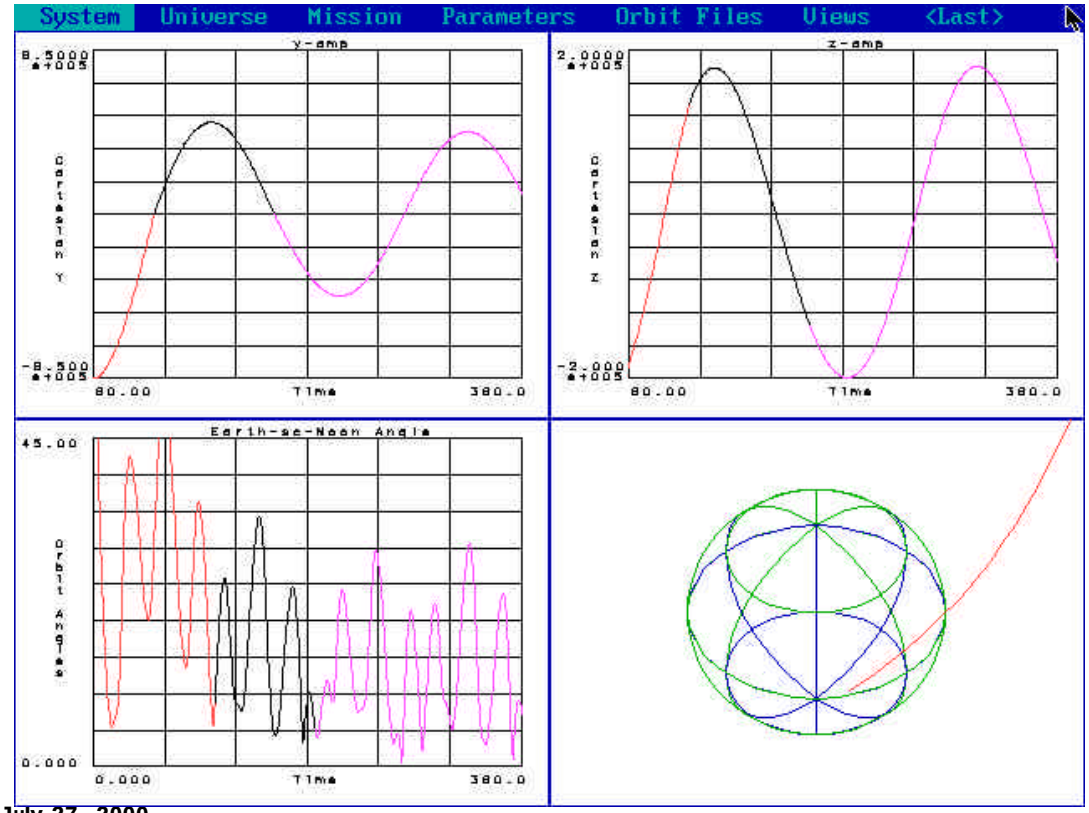


Flight Dynamics
Option 2: Small Lissajous/Direct Transfer



Flight Dynamics
Option 2: Small Lissajous/Direct Transfer

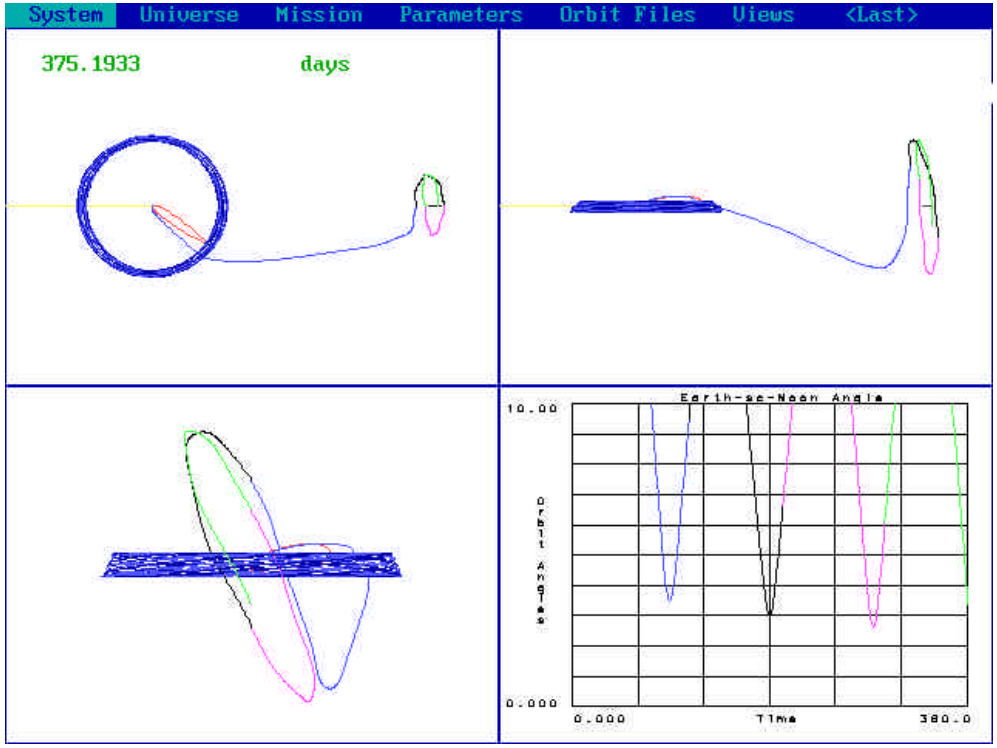
- Y-Amp ~ 400k
- Z-Amp ~ 200k
- Sun-S/C-Moon angles of 0-30 degrees



Flight Dynamics

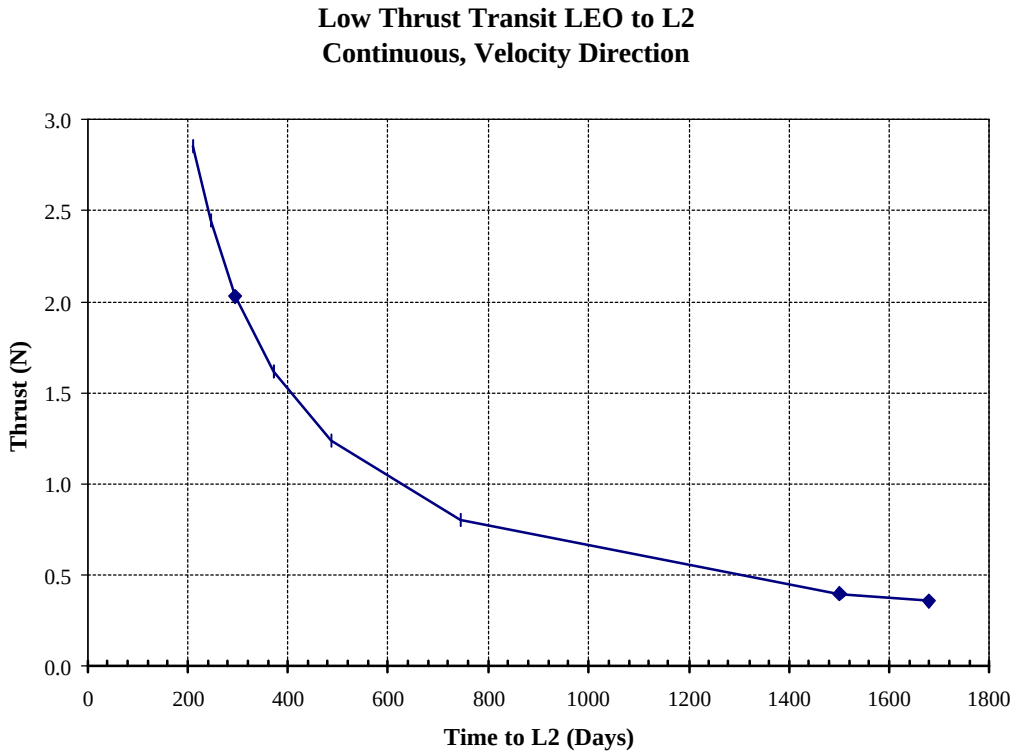
Option 3: Small Lissajous/Lunar Gravity Assist

- Y-Amp ~ 200k
- Z-Amp ~ 300k



Flight Dynamics
Option 4: Continuous Low Thrust

- Long Transfer Times
- Still requires L2 insertion ΔV, typically a high thrust maneuver
- LEO = 355 km, 51 deg
- Inclination change (51 deg) managed continuously



Flight Dynamics
Maintenance and Correction ΔV

- L2 Orbit Maintenance: ΔV ~ <4 m/s per year

- Launch Vehicle Correction ΔV: (error of 3m/s)

  Small Liss **1^d ~ 20 m/s**

  4^d ~ 17 m/s

  Lunar Gravity Assist

  0.33^d ~ 22 m/s,

  1^d ~ 40m/s,

  at perigee ~ 10m/s

- **Total ΔV with maintenance, corrections, etc.**
  - **Large Lissajous: ~ 50 m/s,**
  - **Small Lissajous: ~ 171 m/s**
  - **Small Lissajous: ~ 60+ m/s (Lunar Gravity Assist)**

Flight Dynamics
Other Possible Transfer Options/Concerns

Transfer into elliptical orbit to achieve a lower C3

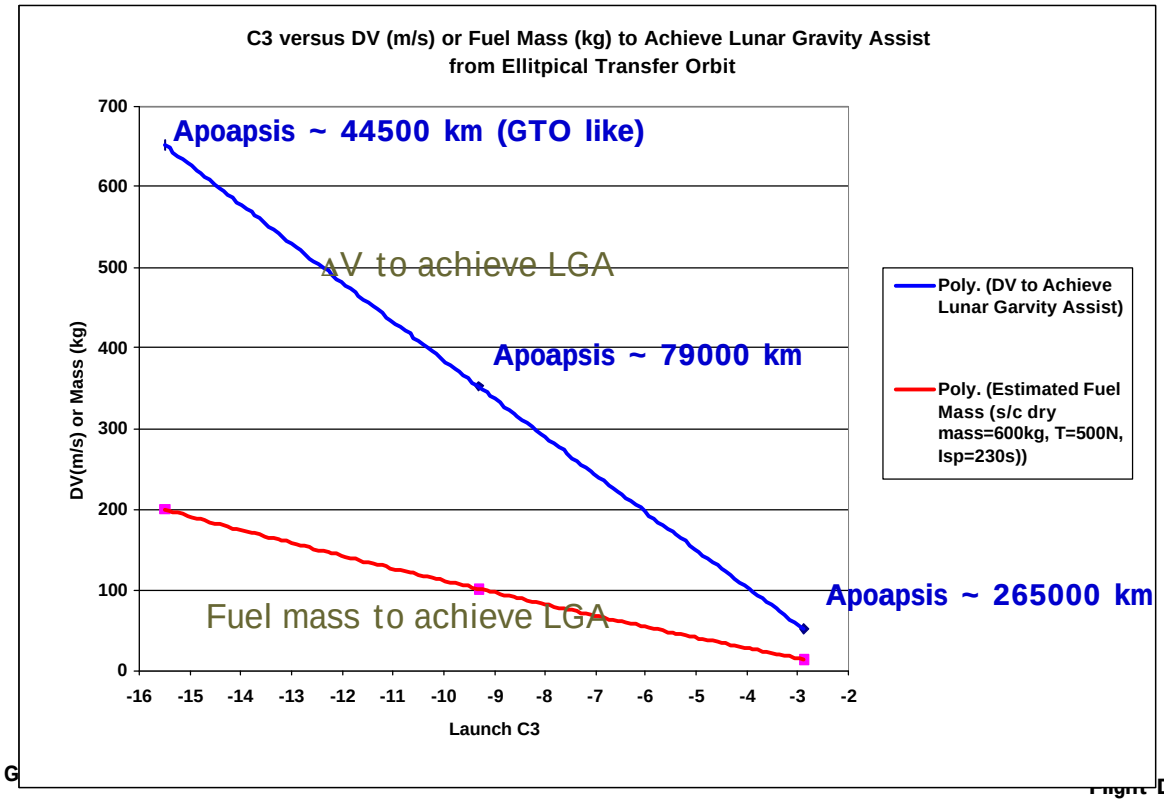
- **ΔV cost of up to ~700 m/s to achieve a Lunar Gravity Assist**
- **Additional ΔV cost of 50-100 m/s to achieve a direct transfer**
- **Does not change final orbit configuration**

LGA Phasing loops will require more ΔV (~20m/s?) to expand launch window for timing with lunar assist

Under performance by Onboard Prop system impact, = contingencies

Flight Dynamics
Other Possible Transfer Options

Transfer into elliptical orbit to achieve a lower C3



Flight Dynamics
Additional Trades to Consider

- **Constellation - Formation Flying**
  - On orbit control and relative dynamics of multiple spacecraft at L2 need to be investigated

- **Drift Orbit - near escape trajectory**
  - No insertion issues (L2), constant distance from Earth, no shadow

Flight Dynamics
Issues and Concerns

- **Adjustments to Analysis**
  - Inclination adjust during Transit
- **Navigation**
  - For Lissajous final configuration, four 15 minute passes per day ranging should ultimately provide 1 km solution, but two week observation arc likely required.
- **Transit times**
  - very high for low thrust options

Flight Dynamics Summary

- Mission Orbit is an L2 Co-linear Libration Orbit
- Direct Launch Window ~ 3 weeks per month with Long and Short parking orbit coast options that effect orbit class
- LGA Launch Window ~ 1-2 weeks per month with Long and Short coast options that effect orbit class and increased phasing loop ΔV budget
- Direct Transfer to mission orbit ~ 100 Days
- Direct Transfer, Large orbit, Requires Most C3, Smallest ΔV
  Direct Transfer, Small orbit, Requires Most C3, Largest ΔV
  Lunar Gravity Assist, Small orbit, Requires Least C3, Med ΔV, with phasing loop ΔVs to open launch window

Flight Dynamics Summary

- No Earth Shadows in transfer or mission orbit
- Lunar shadows depend on size of orbit amplitudes
- Earth to S/C range ~ 1.25 to 1.75 million Km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